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C.H. K. Williamson

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Dr. S. E. Ramberg, Dr. E. Hendricks
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FINAL REPORT OF RESEARCH ON ONR GRANT N00014-90-J-1686

"THREE-DIMENSIONAL ASPECTS OF NOMINALLY 2-D AND 3-D BLUFF BODY WAKES"

P.I. C.H.K.WILLIAMSON

CORNELL UNIVERSITY

Over the last decade, there has been much work carried out to understand three-dimensional effects at low Reynolds numbers (Re) in the wake of bluff bodies, yielding the realization that end effects can influence the vortex shedding across large spanwise lengths. Wake patterns such as parallel shedding, oblique shedding, cellular shedding, transient patterns, such as "phase shocks" and "phase expansions", as well as the existence of large-scale `vortex dislocations', have been investigated, aspects of this research being spearheaded by the studies at Cornell under the above Contract. In particular, we have discovered a new mechanism for oblique wave resonance in the far wake. We have found a means to control the near wake by using suction at the spanwise ends of a body, which has enabled much more precise phenomena to be investigated including the critical conditions for turbulence inception, and a careful study of 3-D wake transition. We have combined our research at Cornell with studies by Dr. Peter Monkewitz at Ecole Polytechnique, Lausanne, who has effectively laid much of the foundation of the description of these near wake patterns in terms of a Guinzburg-Landau equation. For example, the new transient phenomenon known as a "phase expansion" has been found to be directly analogous to a Prandtl-Meyer expansion found in gas dynamics. Clearly, the work under the support of the ONR has led to a surprisingly rich new understanding of three-dimensional effects in nominally two-dimensional wake flows. The importance of these studies lies in the fact that three-dimensionality affects directly the integrated unsteady forces on a long structure, as well as the wake signature left far downstream of a body. There has been a need to extend the reults found over the last 5-6 years to higher Reynolds numbers, and we are attacking these problems precisely at the present time. Our work has involved some other collaboration with groups at Marseille (Provansal), Nice (Pumir) and Caltech (Henderson). Our research under this contract at Cornell has discovered a number of the new phenomena, as well as leading to new understanding of questions in the literature which had remained unanswered for 30-40 years. Our research has directly lead to my invitation to present a review of all of these new findings within the research community in the *Annual Review of Fluid Mechanics*, in a paper entitled **"Vortex Dynamics in the Cylinder Wake"**. It should be said that the Accelerated Research Initiative on Bluff Body Wakes and Instabilities, of which my Grant has been a component, has been the principal trigger for most of the new discoveries, coming from experiment, computation and analytical studies, which I have reviewed comprehensively in the above paper. In particular, our work at Cornell is comprehensively published in several of the principal refereed journals, all of which are listed on the ensuing pages of references coming from support on the above research Contract.